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TSUGA

(hemlocks)

Four of the 10 or more species of hemlocks (*Tsuga*) are North American, 2 eastern and 2 western. The others are in temperate Asia, Himalayas, mainland China, Taiwan, and Japan.

These conifers have slender, nodding leading shoots, irregular horizontal to drooping branches, and deeply furrowed cinnamon-red bark. The rounded buds are not resinous. The needlelike leaves are usually flattened and arranged in 2 rows and have minute petioles above the peglike stalks, which remain on the twigs. The flexible needles are rounded or notched at end, contain 1 resin canal, and persist 3 to 6 years.

Male and ovulate strobili are produced on the same tree in spring from buds of the previous year, the former at leaf bases and the latter terminal. The small egg-shaped or cylindric cones hang down and mature in one season but remain attached until next year. The thin rounded cone scales bear at base paired long-winged seeds. Cotyledons 3 to 6.

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WESTERN HEMLOCK (*Tsuga heterophylla* (Raf.) Sarg.)

Other common names: West coast hemlock, Pacific hemlock, hemlock spruce, western hemlock spruce, western hemlock fir, gray fir, silver fir, and Alaska pine.

Western hemlock grows along the Pacific Coast from Kenai Peninsula in Alaska to northwestern California. It also grows inland in a narrow, scattered pattern along the United States-Canadian border and then spreads out fanlike through northeastern Washington, northern Idaho, northwestern Montana, and through the Selkirk Mountains of southeastern British Columbia. Best stands are found in the humid coastal regions of Oregon, Washington, British Columbia, and Alaska, and on the lower slopes of the Cascade Range in Oregon and Washington.

HABITAT CONDITIONS

Climate

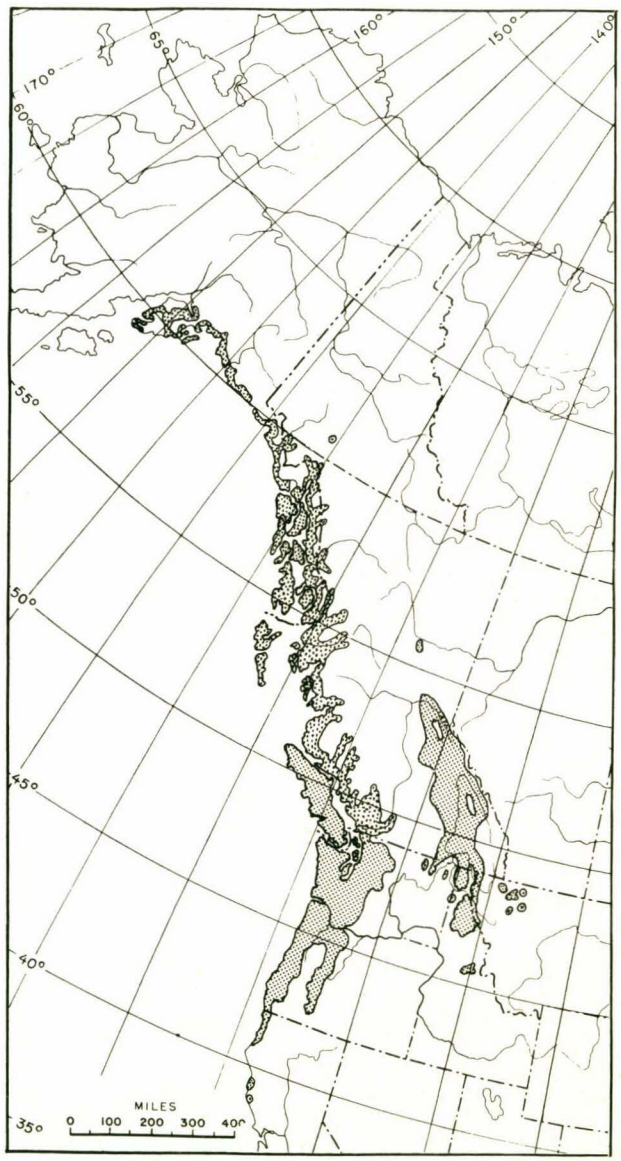
Western hemlock thrives in the humid and mild climate along the Pacific slope, where frequent fogs and rain provide moisture during the growing season. Average annual precipitation in the coastal hemlock region varies from about 150 inches in parts of Alaska and Washington to 38 inches near its southern limit at Eureka, Calif. (table 1). Average precipitation during April to September ranges from 5.5 inches at its southern limit to 65.5 inches at Cordova, Alaska. In the northern Rocky Mountain region, precipitation ranges from 25 to 53 inches a year. Dry summers in this region usually limit the occurrence of western hemlock to the northerly slopes and moist creek bottoms.

Minimum temperatures below −20° F. occur occasionally in the inland range in Idaho, Montana, and British Columbia, and also in parts of Alaska; but elsewhere, especially in the coast region south of Alaska, minimum temperatures are generally above zero. Maximum temperatures range from 82° at Seward, Alaska, to 105° at Aberdeen, Wash., in the coastal forests, and from 100° to 108° in the northern Rocky Mountain Region.

The coastal region is classed in the superhumid zone, and the area between the summits of the Coast and Cascade Ranges and the interior region in the humid zone.

Soils and Topography

Western hemlock occurs on a wide variety of soils derived from sandstones, shales, and igneous rock material, but grows best on deep, internally well-drained soil under high rainfall conditions. It grows well on soils with deep organic layers with adequate moisture. Soil reaction ranges between pH 4.5 and 5.0 along the coast of Oregon and Washington, whereas in Alaska soil pH beneath western hemlock is generally between 3.5 and 4.0. In the white pine type, western hemlock grows in soils with a pH of about 5.5 and occasionally occurs on sites with a pH of 6.0. Soil



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The range of western hemlock.

TABLE 1.—*Climatological data for locations within the commercial range of western hemlock*

Location	Elevation	Average precipitation		Temperature					Frost-free days
				Average			Absolute		
		April–September	Annual	Annual	January	July	Maximum	Minimum	
Coastal range:									
Alaska:	*Feet*	*Inches*	*Inches*	°F.	°F.	°F.	°F.	°F.	*Number*
Seward	76	28. 4	73. 7	39. 5	22. 4	55. 3	82	−20	132
Sitka	15	34. 7	87. 1	45. 6	32. 4	54. 9	87	−5	159
Ketchikan	10	57. 5	150. 9	46. 4	32. 6	57. 5	96	−8	165
British Columbia:									
Masset	30	20. 8	53. 9	45. 6	35. 8	58. 1	84	−2	169
Vancouver	136	15. 9	58. 7	49. 0	35. 6	63. 3	92	2	219
Washington:									
Quinault	220	29. 9	128. 6	50. 9	38. 4	63. 5	104	11	208
Aberdeen	135	18. 7	82. 9	49. 9	39. 2	59. 6	105	6	191
Oregon:									
Newport	115	15. 0	66. 2	50. 9	43. 7	56. 8	100	1	248
California:									
Eureka	64	5. 5	37. 6	51. 5	47. 3	56. 1	85	20	328
Inland range:									
Idaho:									
Bonners Ferry	1,787	5. 9	21. 5	44. 0	21. 7	65. 3	102	−26	143
Avery	2,500	8. 4	31. 7	46. 8	26. 4	67. 1	108	−25	112
British Columbia:									
Revelstoke	1,497	13. 3	39. 7	43. 0	21. 0	65. 0	105	−30	(1)
Glacier	3,778	16. 9	53. 2	36. 0	14. 0	58. 0	95	−32	(1)

[1] Not available.

series of western Oregon and western Washington on which hemlock grows include Astoria, Melbourne, Olympic, St. Helens, Stabler, Elma, and Nawhatzel.

In the arborvitae-hemlock vegetational zone of northern Idaho, soils are derived mainly from the Idaho batholith and represented by the Belt series (*6*).[1] The rocks are largely quartzitic and argillaceous in the former, and quartz manzonite and granite types in the latter. These soils, which are only weakly acid (pH 6), resemble most closely the brown podzolic soils.

Hemlock develops best at elevations between sea level and 2,000 feet along the coast from Alaska to Oregon. In the northern Rocky Mountain Region of Idaho and Montana, it is found at altitudes up to 6,000 feet. In the Selkirk Mountains of British Columbia, it ranges up to 5,000 feet (*20*). Trees become stunted at the extreme elevations even when good soil and moisture are available.

Associated Trees and Shrubs

Western hemlock is usually subordinate in association with Sitka spruce and Douglas-fir, but sometimes dominates and occasionally occurs in pure stands in the coastal areas. From the upper slopes of the coastal mountains and through its inland range, western hemlock generally grows in scattered patches, groups, or singly through the forest. It is one of the major components of the following five types:

Type No.	*Type*
224	Western Hemlock
225	Sitka Spruce—Western Hemlock
226	Pacific Silver Fir—Western Hemlock
227	Western Redcedar—Western Hemlock
230	Douglas-fir—Western Hemlock

Western hemlock is a minor species in 11 other forest types. In the Western White Pine Type it forms part of the dominant stand as well as a distinct understory (*9*).

Type No.	*Type*
202	White Spruce—Birch
205	Mountain Hemlock—Subalpine Fir
206	Engelmann Spruce—Subalpine Fir
213	Grand Fir—Larch—Douglas-Fir
215	Western White Pine
221	Red Alder
223	Sitka Spruce
228	Western Redcedar
229	Pacific Douglas-Fir
231	Port-Orford-Cedar—Douglas-Fir
232	Redwood

Other species with which hemlock grows are Alaska-cedar, noble fir, Engelmann spruce, and California-laurel.

In dense stands scarcely any understory vegetation is present. Where light penetrates to the

[1] Italic numbers in parentheses refer to Literature Cited, p. 722.

forest floor, however, ferns, herbs, and shrubs occur. Shrubs present in abundance are salmonberry (*Rubus spectabilis*), blueberry (*Vaccinium* spp.), red whortleberry (*V. parvifolium*), salal (*Gaultheria shallon*), coast rhododendron (*Rhododendron macrophyllum*), Oregon grape (*Mahonia acquifolium*), and American devilsclub (*Oplopanax horridus*). Vine maple (*Acer circinatum*), although classified as a tree, is also a common shrublike associate.

Shrub species characteristic of hemlock stands of the inland range are not so evident due to the scattered occurrence of this tree species. However, the frequent incidence of devilsclub on moist sites under hemlock stands (*5*) shows a similarity in site requirements over much of the western hemlock range.

LIFE HISTORY

Reproduction and Early Growth

Flowering and fruiting.—Records from 14 stations in western Washington and western Oregon show that pollen shedding begins between April 22 and May 13 and ends between May 3 and May 25. In southeastern Alaska, pollen shedding begins about a month later, but does not extend over as long a period.

The small, solitary, drooping cones ripen during the first year, but remain on the tree after release of seeds until summer or autumn of the second year. Cones are ¾ to 1¼ inches long at maturity and hold approximately 30 to 40 seeds each. The small seeds are about 1/16 inch long and average 300,000 per pound.

Seed production and dissemination.—Western hemlock is a very prolific seeder. It produces some seed every year and heavy seed crops every 3 or 4 years. Cones are sometimes found on trees less than 20 years old, but seed-bearing usually starts between 25 and 30 years. Open-grown trees frequently acquire a hue ranging from purple to bronze—the result of a heavy cone crop adorning the full length of the crown. Even trees in dense stands produce heavy cone crops.

Records on the Oregon Coast showed that more than 8 million viable seeds per acre were released during each of 2 years from 100-year-old stands (*18*), or about 27 pounds per acre annually. A bumper crop in Alaska during 1951 produced 91 pounds of seed per acre in a spruce-hemlock forest; 86 pounds were hemlock seed (*8*). Even scrubby stands on poor sites produce good seed crops (*11*). In stands on Vancouver Island, with only two-thirds as many stems as its associate Douglas-fir, understory hemlock produced three times as many seeds (*7*). Here, more than half the hemlock seed was retained on the trees until spring. Inland hemlock consistently outproduces white pine and its principal associates in both frequency of cone crops and quantity of seed. This characteristic explains in large part the abundance of western hemlock in certain parts of the white pine type (*9*).

Hemlock seed may be carried considerable distances by wind. When released at 200 feet elevation in a 12.5 m.p.h. wind, seed traveled as far as 3,800 feet, but most fell within 2,000 feet from point of release (*10*). Western hemlock seed occasionally is blown more than a mile from its source. However, 10 to 15 times as many seed fall to the forest floor under a dense stand as on adjacent clear-cut openings within 400 feet of timber's edge (*7*, *12*, *18*).

Cones generally begin to open between September 3 and October 6, but on one area on the Oregon Coast seed fall consistently began during the latter part of October with 90 percent of the seed falling by February (*18*). In this area, seed fall is greatly accelerated during periods of dry off-shore winds, but may be extended over a period of several months or even postponed until late fall or winter if moist winds persist.

There is not much known about seed destruction by insects, diseases, or animals although only a small percentage of the seed produced usually germinates. Seed chalcids (*Megastigmus* spp.) infest hemlock seeds but the extent of damage has not been determined.

Seedling development.—If adequate moisture is available, germination under forest conditions is excellent on such diverse materials as moss, humus, decaying litter, and mineral soil. Seedlings are often abundant under mature stands and also on moist seedbeds in open or clear-cut areas. In the coastal region, where the forest floor is often deeply covered with herbs, ferns, and shrubs, the small seeds of western hemlock often germinate only on stumps and trunks of fallen trees. On these seemingly precarious seedbeds some seedlings survive, sending roots into the ground around or through the stump or trunk, and eventually grow to maturity.

Animal damage to seedlings is usually a minor problem, although deer browsing is common in some areas. Rabbits and mountain beaver also feed on hemlock seedlings in some areas. Occasionally mice will chew the bark off seedling stems. In the white pine type, hemlock is considered most susceptible to drought; resistance to drought is linked closely with depth of initial root penetration (*9*).

Because western hemlock is very tolerant and germinates and survives under a wide variety of seedbed conditions, natural regeneration can be obtained through many harvesting methods varying from individual tree selection to clear cutting. Shelterwood cuttings provide favorable conditions for hemlock regeneration, but must be used cau-

tiously where there is danger of exposing the stand to wind damage or where a preponderance of hemlock in the stand is not desired, as in the white pine type.

Height growth of western hemlock seedlings is usually slow during establishment. On the Oregon coast, 3-year-old seedlings were only 6 to 7 inches tall, even when free to grow (*3*). Near Grays Harbor, Wash., 2–0 planting stock grew only 2 inches during a 2-year period following planting (*21*). After establishment, however, western hemlock commonly grows 2 feet annually in height in full overhead light.

Vegetative reproduction.—Western hemlock can be propagated by layering (*4*) and from cuttings. It does not sprout from roots or the stump.

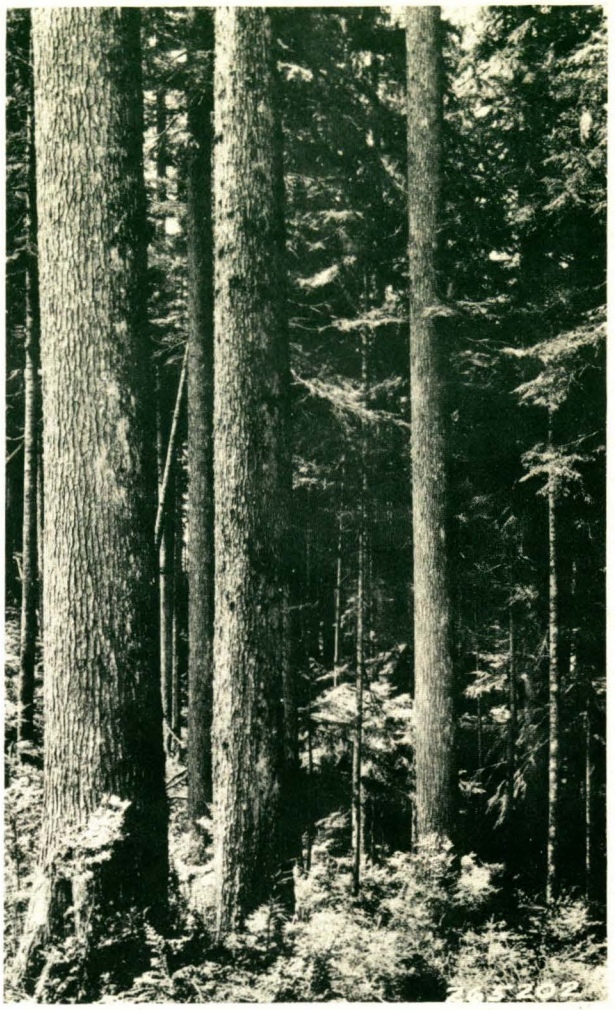
Sapling Stage to Maturity

Growth and yield.—Under the best growing conditions, trees grow to 3- to 4-foot diameters and 175- to 225-foot heights. Larger trees are found, but those over 5 feet in diameter are rare.

Twenty-year-old stands of western hemlock may contain 2,000 stems per acre or more, with volumes from 400 cubic feet per acre on poor sites to 2,600 cubic feet on the best sites. Tree measurements and volumes for 100-year-old stands in Oregon and Washington are shown in table 2. Old-growth stands often contain only half the volume of vigorous young stands (*1*). Cubic-foot yields of western hemlock stands in British Columbia and Alaska for a given site are quite similar to those of stands in Oregon and Washington, but board-foot yields decrease progressively northward. The northern stands have more trees per acre, but average tree diameter is less. It is significant, also, that stands of site quality I and II become increasingly scarce toward the northern limits of coastal western hemlock stands.

Reaction to competition.—Western hemlock is rated as very tolerant (*2*), about the same as Port-Orford-cedar, Pacific silver fir, and Pacific yew. In the coastal forests, western hemlock is more tolerant than Sitka spruce and Douglas-fir, but less tolerant than Pacific silver fir.

Hemlock usually responds well to release after long periods of suppression. Understory reproduction, 50 years old, developed into a vigorous young-growth stand following complete removal of the overstory (*17*). In contrast, poor response to release of suppressed trees over 100 years old has been noted in Alaska (*1, 19*). When western hemlock develops in a dense even-aged stand, natural pruning takes place early. Under these conditions tree crowns are usually narrow and short, and trunk development is favorable. When given unrestricted growing space, however, or if it develops as an understory tree, the quality of western hemlock is substantially reduced by persistent branches and poor form.



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Old-growth western hemlock in Washington

The pure western hemlock forest is a true climax type, following the subclimax types of Sitka spruce and of Douglas-fir west of the Cascades, and of western white pine in the northern part of its inland range. Sitka spruce, western redcedar, and Pacific silver fir sometimes persist in the hemlock climax type.

Principal enemies.—Chief causes of mortality in young-growth western hemlock are wind and snow. Losses from snow-break are most severe in the inland range, especially in thinned stands (*9*); wind is the main cause of loss in coastal forests. In dense stands, a large number of trees also die from suppression during stand development.

A number of trunk, butt, and root rots, including *Fomes annosus*, *F. pini*, *Poria weirii*, *P. subacida*,

TABLE 2.—*Average tree dimensions, density, and timber volumes per acre for fully stocked 100-year-old western hemlock stands in Oregon and Washington* [1]

Site class	Average tree dimensions		Density (trees per acre) [2]	Volume per acre	
	D.b.h.[2]	Height [3]		Cubic [2]	International ⅛-inch rule [4]
	Inches	*Feet*	*Number*	*Cubic feet*	*Board feet*
I	23. 2	200	121	25, 300	187, 000
II	21. 6	170	137	21, 400	157, 000
III	19. 4	140	166	17, 400	129, 000
IV	16. 5	110	213	13, 300	98, 000

[1] Barnes, George H. 1962. Yield of even-aged stands of western hemlock. U.S. Dept. Agr. Tech. Bul. 1273, 52 pp.

[2] All trees 1.6 inches d.b.h. and larger.

[3] Average height of dominant and codominant trees only.

[4] All trees 6.6 inches d.b.h. and larger.

Echinodontium tinctorium, and *Polyporus circinatus*, are common on western hemlock. These decays are usually much more destructive in old-growth than in young-growth stands (*14*, *15*). In the inland range, however, infection by *E. tinctorium*, Indian paint fungus, often occurs comparatively early in the life of the tree. In a study here [2] infection was first detected in trees 41 to 80 years of age. Forty-six percent of the trees in this age group were infected. Susceptibility of hemlock to this heart rot is largely responsible for the frequent classification of this tree as an inferior species in the western white pine type (*9*).

Dwarfmistletoe (*Arceuthobium campylopodum*) is a common parasite on western hemlock. It increases mortality, especially of mature trees, and reduces growth in trees of all sizes.

The most important insects that attack western hemlock are the hemlock looper (*Lambdina fiscellaria*), the black-headed budworm (*Acleris variana*), the western larch roundheaded borer (*Tetropium velutinum*) and the hemlock sawfly (*Neodiprion tsugae*).

Four of five major outbreaks of the hemlock looper have occurred along the coast of Oregon, Washington, and British Columbia during the last 60 years. The most recent outbreaks occurred between 1943 and 1945 on the Oregon Coast and covered some 12,000 acres with a timber loss of 40 million board feet. The epidemic was halted

[2] Hubert, Ernest E. First progress report on the study of decay in western hemlock. Unpublished report, U.S. Forest Serv. Region 1. 1929.

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Western hemlock reproduction following a clearing for a road, filling in under Sitka spruce and hemlock.

by aerial spraying with DDT. Scattered outbreaks occurred again in 1961.

An outbreak of the black-headed budworm in Washington in 1944 and 1945 resulted in large acreages of defoliated trees, but only a small amount of killing. On Vancouver Island, British Columbia, however, an outbreak in the early 1940's killed a large volume of western hemlock. In 1957, a second large outbreak covering some 150,000 acres and threatening about 3 billion board feet of hemlock is believed to have been controlled by aerial spraying with DDT. Serious defoliation occurred on the Tongass National Forest in Alaska between 1948 and 1955 (*16*).

The western larch roundheaded borer is an important killer of hemlocks that have been weakened by defoliators such as the looper and black-headed budworm. It continues to kill trees in large numbers for several years following the end of defoliator outbreaks. The hemlock sawfly occasionally becomes epidemic and defoliates extensive areas along the Pacific Coast.

Fire and wind also cause considerable losses in western hemlock stands. Thin bark and occurrence of exposed roots are reasons for a high rate of susceptibility to fire damage. Losses from wind are due mainly to the shallow rooting characteristics of this species.

RACES AND HYBRIDS

A natural cross between western hemlock and mountain hemlock (*Tsuga ×jeffreyi*) is reported in the Mount Baker area where both assumed parents are found growing together (*13*). Natural specimens of this hybrid are not easily recognized, probably being passed over as a green-leaved form of mountain hemlock.

Revised from "Silvical Characteristics of Western Hemlock," by Carl M. Berntsen. U.S. Forest Serv. Pacific Northwest Forest and Range Expt. Sta. Silvical Ser. 3, 16 pp. 1958.

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